WRRI NEWS
Water Resources Research Institute
of The University of North Carolina
www.ncsu.edu/wrri

ISSN 0549-799X
Number 376 October-December 2011

Could North Carolina's Triassic Basin be the next shale gas "play"?

by Jeri Gray

According to some people, plentiful natural gas from domestic unconventional sources, principally shale formations, can fuel America's return to economic prosperity, free the country from dependence on imported oil, eliminate the need to use dirtier fuels like coal, and bridge the way to and provide backup for renewable energy. For localities lucky enough to have shale gas resources, production of natural gas can provide income for landowners, create jobs, and provide revenue for cash-strapped state and local governments, they say. The U.S. Department of Energy has committed millions of taxpayer dollars to research and development of natural gas technologies, and President Obama has cited natural gas as an important part of his Blueprint for a Secure Energy Future.

Other people question this bullishness. They question the safety of processes used to produce shale gas. They worry about water demand associated with production of shale gas, treatment of wastewater generated by it, the possibility of contamination of groundwater, and seismic activity generated by the technology. They doubt the rosy economic projections, and they point out the legal uncertainties regarding landowner rights. Local officials worry about the impact on infrastructure and quality of life in communities where drilling might take place.

Since the N.C. Geological Survey (NCGS) reported in 2009 that Triassic organic black shale in the Comnock Formation of the Deep River Basin potentially could produce commercial quantities of natural gas, gas companies have been buying leases from landowners, and debate has been growing about whether to encourage exploitation of this resource and change state law to allow the drilling and production practices—horizontal drilling and hydraulic fracturing—needed to extract shale gas.

In its last regular session, the N.C. General Assembly passed House Bill 242, which—among other things—instructs the N.C. Department of Environment and Natural Resources (NCDENR) to study "the issue of oil and gas exploration in the state and specifically the use of directional and horizontal drilling and hydraulic fracturing." The study is to include potential impacts on infrastructure and the environment, economic and social impacts, regulatory issues, and consumer protection and legal issues. A report on the study is to be presented to the legislature's Environmental Review Commission by May 1, 2012.

Another bill, Senate Bill 709, directly requiring the state to move forward with both onshore and offshore energy development was passed by the legislature but vetoed by Governor Purdue. It is expected that backers of the bill will attempt an override. This bill would direct NCDENR to complete a study that "outlines the commercial potential of onshore shale gas resources

continued on page 2

In this issue **October-December 2011**

Page

Shale gas *continued from page 1*

within the State as well as the regulatory framework necessary to develop this resource." It would establish the Energy Jobs Council whose job it is to "identify and utilize all domestic energy resources to … promote job creation and expand business and industry opportunities while ensuring the protection and preservation of the State's natural resources, cultural heritage and quality of life." If the veto of 709 is overridden, NCDENR will be required to conduct its study in conjunction with the Energy Jobs Council.

A primer on shale gas

Estimates of proven natural gas reserves in United States have increased significantly over the last decade largely because technology has made it possible to extract "unconventional" sources of natural gas. According to the Energy Information Adminstration's 2011 energy outlook, the United States possesses more than 2,552 trillion cubic feet (Tcf) of potential natural gas resources—enough to supply all the country's natural gas demand at current rates of consumption for 110 years. Shale gas is perhaps the most important of the "unconventional" sources of natural gas, with more than 800 trillion cubic feet of potential reserves.

While "conventional" natural gas deposits have well defined areas and are porous and permeable, "unconventional" sources are geologically diverse, dispersed over large areas, nonporous, and require stimulation to extract. Shale is fine-grained sedimentary rock that forms from the compaction of silt and clay-size mineral usually thousands of feet below the surface. It is made up of many thin layers that readily split into thin pieces along the layers. Black shales contain organic material that sometimes form natural gas or oil that is prevented from migrating toward the earth's surface by the low permeability of the rock and is trapped within the pore space and natural fractures of the shale.

Sources of shale gas have been under exploration since the early 1980s, but because the difficulty of extracting shale gas made it more costly than conventional gas, the resource was largely ignored until 1995. That's when Mitchell Energy improved hydraulic fracturing technology and its successor, Devon Energy, combined it with horizontal drilling to achieve huge increases in gas production in the Barnett Shale play of Texas. Over the next decade more than 13,500 producing shale gas wells were drilled in the Barnett Shale play alone and thousands more have since been drilled in the Woodford Shale in Oklahoma, the Haynesville Shale in east Texas and northwestern Louisiana, the Brakken Shale in North Dakota and Montana, the Fayetteville Shale in Arkansas, and the Marcellus Shale in the Appalachian Basin which extends through Pennsylvania, New York, Ohio, and West Virginia.

The technology

When a shale gas well is constructed, tubes of steel called casing are placed in a borehole. Following initial drilling and placement of a conductor pipe, three levels of casing–progressively smaller in diameter—are fitted together: a surface casing, an intermediate casing (if deemed necessary) and a production zone casing.

The surface casing is placed to a depth below the deepest occurrence of fresh groundwater. State regulations are relied upon to determine the required depth of the surface casing. The surface casing is cemented into place. Industry recommendations are that the entire length of surface casing

continued on page 3

ISSN 0549-799X
Number 376
October-December 2011

This electronic newsletter is published by the Water Resources Research Institute of the University of North Carolina. It is financed in part by the Department of the Interior, U.S. Geological Survey, as authorized by the Water Resources Research Act of 1964. You may sign up to receive the electronic newsletter via an electronic listserv by sending an email to water_resources@ncsu.edu.

WRRI
NC State University, Box 7912,
Raleigh, NC 27695-7912
water_resources@ncsu.edu
http://www.ncsu.edu/wrri/

Shale gas *continued from page 2*

be cemented.

The intermediate hole penetrating the strata between the groundwater zone and the production zone is drilled, and the intermediate casing is placed and cemented, although not necessarily the entire length. At this point, pressure testing may take place to determine the maximum pressure that the casing string can withstand and to test the integrity of the cement.

Finally, the borehole is drilled to the producing zone. When the drill reaches the shale, it turns to drill horizontally and may extend hundreds of feet into the shale layer. Then, production casing is placed and sealed off with "packers" and cemented in place. The production zone is typically thousands of feet below the freshwater aquifers. According to the industry, this process seals freshwater aquifers off from the wellbore by two or three levels of casing and cement so that fluids placed in the wellbore cannot enter drinking water aquifers.

After a perforating gun blasts holes in the horizontal casing and cement, fracturing takes place. First, to initiate fractures in the rock and get the gas flowing, fluid is pumped into the production zone at high pressure. Pressure may range up to 15,000 psi with a flow rate of 100 barrels or 4,200 gallons a minute. When pumping stops, the fractures snap closed, pushing the fluid back into the borehole, back up the well, and back to the surface, where it must be captured and contained. Then a "proppant," which can be as simple as sand or can be a complex mixture of materials, is pumped into the fractures to prop them open so gas can migrate into the production well. Then the production zone is flushed to force proppant further into the cracks and to remove excess proppant. Water may be used to flush the well or the well may be flushed with the same fluid used to frack the zone. An interactive video on the National Geographic website provides a good visual explanation of shale well development: http://news.nationalgeographic.com/news/2010/10/101022-breaking-fuel-from-the-rock/

Developing a shale gas well requires that four to six acres of surface area be cleared for the pad, the waste pit, and the numerous pieces of equipment required for the operation, including drilling rigs, generators, pumps, tanker trucks, mixers and more. Drilling and fracturing are noisy and can last from two weeks to more than a month. Two to five million gallons of water per well may be used in the drilling and production process.

Environmental concerns

Environmentalists, some people who live in shale gas production areas, and some politicians believe that gas production—particularly hydraulic fracturing—should be more tightly regulated because industry practices threaten groundwater, surface water, air quality and the quality of life in communities where well development takes place.

Studies have shown that engine exhaust and emissions from drilling and fracturing as well as gas production include smog-forming compounds (nitrogen oxides and volatile organic compounds), greenhouse gases (carbon dioxide and methane), and air toxic chemicals, including benzene and formaldehyde, and that local and regional impacts from these emissions are serious.

The threat to groundwater, opponents say, comes from the possibility that fracturing fluids containing toxic substances can migrate into drinking water aquifers either through defective well casings or vertical fractures opened by the fracturing process or from seepage from pits used to store wastewater. They point to instances of confirmed drinking water contamination with substances known to be in fracturing fluids as well as benzene and methane; to spills of fracturing wastewater; to methane explosions; and to earthquakes all associated with hydraulic fracturing of gas shales:

- In Pavillion, Wyoming, where hundreds of gas wells are operated by EnCana in the Barnett Shale, EPA sampling in 2009 found widespread incidence of low levels of organic compounds in drinking water wells with detections of total petroleum hydrocarbons, naphthalene, phenols and methane. In three wells EPA found a compound called 2-butoxyethanol, known as 2-B, a substance known to be used in fracturing fluids. Residents there had asked EPA to investigate because of long-standing health concerns. EnCana said that the substances occur naturally and were unrelated to drilling. EPA also found groundwater contamination under three wastewaste pits in Pavillion. According to *Wyoming Energy News*, Wyoming officials had already ordered cleanup of 25 other wastewater pits in the area.
- In Sublette County, Wyoming, home to more than 6,000 wells, a Bureau of Land Management monitoring program documented benzene in water wells.
- Methane has been found in water wells in several Pennsylvania communities where gas production is taking place, and the Pennsylvania Department of Environmental Protection has ordered Cabot Oil and Gas to shut some wells, pay fines and provide water to residents of the community of Dimock.

continued on page 4

Shale gas *continued from page 3*

- In June 2011, the Colorado Oil and Gas Conservation Commission fined Berry Petroleum and Marathon Oil for two separate spills amounting to hundreds of thousands of gallons of wastewater containing fracturing fluids in Parachute County. Chemicals flowed into Parachute Creek and ultimately into the Colorado River, prompting concern from ranchers and state wildlife officials. In 2009 in Caddo Parish, Louisiana, regulators blamed the death of seventeen cattle on fracturing fluids that leaked from a well pad and ran into the adjacent pasture.
- In December 2007, the Ohio Department of Natural Resources, Division of Mineral Resources Management began an investigation into the explosion of a home in Geauga County where gas wells have been drilled into the Silurian "Clinton" sandstone. According to a report on the investigation, "The DMRM determined that accumulation and confinement of deep, high-pressure gas in the surface-production casing annulus [the void between casings] of the English #1 well [owned and operated by Ohio Valley Energy Systems] resulted in over-pressurization of the annulus. This over-pressurized condition resulted in the invasion, or migration, of natural gas from the annulus into natural fractures in the bedrock below the base of the cemented surface casing. This gas migrated vertically through fractures into the overlying aquifers and exited the aquifers through local water wells."
- In the last four months of 2010, Guy, Arkansas, which sits above the extensively drilled Fayetteville Shale play experienced 500 earthquakes—more than all the previous quakes in the state's history. In 2010, Oklahoma, which usually has about 50 earthquakes a year, experienced 1,047 quakes. An Oklahoma Geological Survey investigation found a correlation between the commencement of hydraulic fracturing in the Eola Field and the increase in earthquake activity.
- In February 2011, the U.S. Army Corps of Engineers, Fort Worth District, asked the City of Grand Prairie, TX, to impose a six month moratorium on approval of drilling and hydrofracturing with 3,000 feet of its Joe Pool Dam because of concerns "that fracturing activities at Chesapeake Energy's Corn Valley drill site may increase the risk to the project and possibly contribute to a catastrophic dam failure." In most of Texas and several other states, the Corps will not allow new wells, drilling pads or pipelines within 3,000 feet of its dams and water control structures.

These and other events are cause for the growing public concern about the environmental effects of shale gas production that was noted by a board appointed under a mandate from President Obama to "improve the safety of shale gas development." Named by Secretary of Energy Steven Chu, the Secretary's Energy Advisory Board (SEAB) released a draft report in August 2011 in which it warned:

> *There are serious environmental impacts underlying these concerns and these adverse environmental impacts need to be prevented, reduced and, where possible, eliminated as soon as possible. Absent effective control, public opposition will grow, thus putting continued production at risk. Moreover, with anticipated increase in U.S. hydraulically fractured wells, if effective environmental action is not taken today, the potential environmental consequences will grow to a point that the country will be faced with a more serious problem. Effective action requires both strong regulation and a shale gas industry in which all participating companies are committed to continuous improvement.*

Exemptions from federal regulation

The oil and gas industry has broad exemptions from federal environmental statutes:

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) was adopted to regulate the management and clean-up of hazardous waste and to provide a way to hold those who cause releases financially responsible. However, release of crude oil or any fraction of crude oil and natural gas or gas liquids do not trigger CERCLA liability.

The Resource Conservation and Recovery Act (RCRA) creates a federal "cradle-to-grave" hazardous waste management program to protect the environment and human health. However, many types of large volume "special wastes intrinsically derived from primary [oil and gas] field operations" are exempt from RCRA Subtitle C management requirements.

The Safe Drinking Water Act's (SDWA) Underground Injec-

continued on page 5

Shale gas *continued from page 4*

tion Control Program (UICP) was established to protect drinking water aquifers by regulating how fluids may be pumped underground. However, injection of fracturing fluids (other than diesel fuels) related to oil and gas production is exempt from regulation under the SDWA. Moreover, under the UICP framework, RCRA-exempted oil and gas wastes can be injected into underground wells with fewer regulatory controls than RCRA-classified hazardous wastes.

The Clean Water Act was enacted to regulate the discharge of pollutants into surface water of the United States. Through its National Pollutant Discharge Elimination System stormwater permitting program, the CWA regulates polluted stormwater runoff from many sources, including city streets, construction sites, and industrial facilities. However, oil and gas production sites are exempt from NPDES stormwater permitting for their "uncontaminated" stormwater discharges regardless of the disturbed acreage at the site unless the discharge is shown to be polluting surface water.

The Clean Air Act (CAA) authorizes establishment of National Ambient Air Quality Standards (NAAQS) to control air pollutants to protect public health and the environment. Oil and gas production is largely unregulated under the CAA due to a provision that prohibits "aggregation" of the many small sources at a production site (wells, compressors, etc.) to determine if the site is subject to regulation.

The Toxic Release Inventory of the Emergency Planning and Community Right-to-Know Act (EPCRA) provides to the public information about chemical use and release or transfer, including transfer to a municipal wastewater treatment plants. The oil and gas industry is not required to report its chemical use or release.

Possible new federal regulations?

In response to a consent decree resulting from a suit by environmental groups, the US Environmental Protection Agency (EPA) in July 2011proposed four new regulations under the Clean Air Act that would establish two new-source performance standards and two air toxics standards for the oil and gas industry. Under the consent decree EPA was supposed to issue final standards by February 28, 2012 but in October was granted an extension to April 3, 2012, and extended the public comment period.

EPA has also initiated information gathering in preparation for proposed rulemaking to set pretreatment standards for wastewater from shale gas operations discharged to public and private wastewater treatment plants—unless the information gathering phase shows that wastewater from shale gas operations is already adequately treated. Proposed rules are expected in 2014.

At the direction of the U.S. House of Representatives, EPA has also launched a study of the potential impacts of hydraulic fracturing on drinking water and groundwater. The study will examine (among other things) the potential impacts of large volume water withdrawals, impacts of surface spills of fracturing fluids and flowback and produced water, the potential for subsurface migration of fluids and gases into groundwater and the local geologic features that might allow such migration, and the potential impact of disposal into surface waters of treated fracturing wastewater. Preliminary results are expected by the end of 2012.

The importance of state regulation

Even though EPA is in the rulemaking process for air and wastewater regulations related to shale gas production, the outlook for new federal regulation of the oil and gas industry is not good.

In 2009 when legislation was introduced in Congress to regulate hydraulic fracturing under the Safe Drinking Water Act, the American Petroleum Institute and IHS Herold, a leading information and research provider for the energy industry, made public their analyses showing that U.S. gas production would drop 20% to 22% over the first 5 years if federal regulation of hydraulic fracturing became law. The proposed legislation, the Fracturing Responsibility and Awareness of Chemicals Act, never made it out of committee. (The legislation was reintroduced in March 2011.)

The final report released by the DOE's SEAB in November made a number of recommendations for reducing the environmental impacts of shale gas production, but none of the recommendations directly support imposing new federal regulations. The report instead recommends that states participate in the voluntary review of their regulatory programs by the non-profit State Review of Oil and Natural Gas Environmental Regulations.

In addition, in September, more than 100 organizations—gas companies and industries but also local chambers of commerce, the American Farm Bureau Federation, the Georgia Rural Groundwater Association, the National Taxpayers Union, Citizens Against Government Waste, Dow Chemical Co., the Bowling Centers Association of Ohio and the North Dakota Grocers Association—signed a letter to President Obama asking that he "continue

continued on page 6

Shale gas *continued from page 5*

to support the development of this vital energy source [shale gas] here in the United States and also support the hydraulic fracturing technology that is indispensable to making its development possible." The signers also say:

> *[S]tate regulators have the primary responsibility to conduct inspections, oversee well construction, test wells, track well plugging, and monitor the fracturing process itself. Because they understand the regional and local geological conditions, they are in the best position to protect groundwater and drinking water sources.*

As states now do, states probably will in the future provide the primary protection from environmental impacts of shale gas production.

North Carolina law and regulations relevant to shale gas production

Current North Carolina law and regulations prohibit horizontal drilling and hydraulic fracturing.

The North Carolina statutes relating to Oil and Gas Conservation (Chapter 13, Subchapter V) provide that "Whenever the Department fixes the location of any well or wells on the surface, the point at which the maximum penetration of such wells into the producing formation is reached shall not unreasonably vary from the vertical drawn from the center of the hole at the surface." This law is codified at 15A NCAC 05D .0107 (e) providing that "all wells shall be drilled in such a manner so that vertical deviation of the hole does not exceed three degrees between the bottom of the hole and the top of hole."

North Carolina code governing underground injection wells (15A NCAC 02C .0209) prohibits the use of wells to inject fluids "which are brought to the surface in connection with conventional oil or natural gas production" and "for enhanced recovery of oil or natural gas."

Therefore, to permit hydraulic fracturing in North Carolina, state law and regulations would have to be amended. Legislation passed in the last session of the N.C. General Assembly makes it clear that the majority of current lawmakers favor developing domestic sources of offshore and onshore oil and gas. If laws and rules were changed to permit hydraulic fracturing, the current oil and gas conservation law gives the Department of Environment and Natural Resources authority to "make rules and orders … to prevent the pollution of freshwater supplies by oil, gas or salt water or to protect the quality of the water, air, soil or any other environmental resource against injury or damage or impairment" and specifically "to regulate secondary recovery methods, including the introduction of gas, air, water or other substances into producing formations."

The study now underway by DENR is aimed at determining what additional regulation would be desirable if hydraulic fracturing is permitted.

The North Carolina study

Under the mandate of House Bill 242, NCDENR began its study in October and has held one public hearing principally to take comment on concerns and issues. On December 13, DENR announced changes in the scope of the study in response to comments (http://portal.ncdenr.org/c/journal/view_article_content?groupId=21953&articleId=5028455). According to Trina Ozer of NCDENR, who is coordinating the study, at least one more hearing will be held—perhaps in March 2012—to present information (possibly a draft report) and take additional comment.

To help assess the regulatory changes needed to effectively oversee and govern shale gas production in the state, NCDENR called in the nonprofit State Review of Oil and Gas Regulations (STRONGER). STRONGER was established by the U.S. EPA and the Interstate Oil and Gas Compact Commission to review state regulatory programs associated with oil and gas exploration, development and production. It is funded by EPA, the federal Department of Energy and the American Petroleum Institute.

The STRONGER review team met for several days in October and questioned representatives of the Divisions of Land Resources, Water Quality, Waste Management and Air Quality to learn about the state's regulatory program. They then began writing a report that will compare state regulations to STRONGER guidelines. The report is expected to be complete by the end of February of 2012.

The Play

The urgency with which North Carolina needs to establish a regulatory program for shale gas production could be determined by the strength of evidence for an economically viable "play" in the Cumnock formation. The NCGS has collected extensive geophysical, geochemical, seismic, and well data and has turned the data over to the U.S. Geological Survey for statistical analysis. The USGS analysis—due around Christmas—is expected to provide an evaluation of the hydrocarbon potential of the formation.

A list of sources used in writing this article is available on the WRRI website at: http://ncsu.edu/wrri/code/publications/currentpublications.htm

Working paper from Duke University identifies environmental issues related to shale gas for focus of regulatory action in North Carolina

A recently released working paper from the Duke University Nicholas Institute for Environmental Policy Solutions and the Nicholas School of the Environment focuses on the range of environmental issues that North Carolina lawmakers will need to understand if they consider allowing natural gas production through horizontal drilling and hydraulic fracturing. Drawing on experiences and actions in other states, guidelines from STRONGER, and recommendations of the U.S. Department of Energy's Secretary of Energy Advisory Board (SEAB) Shale Gas Subcommittee, the authors advise consideration of the following:

Pre-drilling Information Needs and Regulatory Structure: Some states where natural gas production has been expanding rapidly have found that they lack comprehensive baseline data and sufficient staff and funding to effectively manage environmental impacts of exploration and production. Without reliable baseline data, regulators find it difficult to distinguish between pre-existing drinking water well contamination and contamination caused by hydraulic fracturing. The authors say that because oil and gas production has not previously occurred in North Carolina, the state has the ability to compare water samples collected before, during, and after each stage of drilling to allow the industry and regulators to identify and address problems early. In order to identify contamination from hydraulic fracturing operations, chemicals used in the process must be disclosed.

Lawmakers will need to select an existing agency or create a new one to manage the permitting and regulatory oversight of gas production and to fund the agency adequately. To fund the increased administrative burden of regulating the shale gas industry, lawmakers could consider the fees and severance taxes imposed by other states.

Regulation of Drilling Operations: Development of a shale gas well requires between two and five million gallons of water, depending on the geology of the area. Withdrawal of surface and/or ground water used for the process is localized and occurs within a moderately short timeframe. If the withdrawals occur during drought or periods of low stream flow, the impacts could be serious. Other states require reporting or permitting of water withdrawals for gas production and encourage recycling.

The state must determine the extent to which local governments will be allowed to regulate land use and other local impacts and whether individual property rights will be adequately protected.

The state will be responsible for regulating treatment and disposal of the significant amounts of flowback fluid and brine or salt water produced during well development. The impacts of possible disposal options, including underground injection, treatment at public or private wastewater treatment plants, and land application must be understood. Some states have prohibited underground injection because of the risk of earthquakes. States have also found that wastewater treatment plants cannot adequately treat the high level of total dissolved solids in produced water, and research has revealed significant negative environmental impacts from land application.

Air emissions from shale gas drilling and production include precursors to ground-level ozone, hazardous pollutants and greenhouse gases. In addition to local air quality impacts, the effects of shale gas production on the Triangle area's ability to attain the 8-hour ozone standard will be important considerations.

Addressing Spills and Other Accidents: In other states, accidents, cement failures, insufficient blowout prevention equipment, equipment failures due to excessive pressure, and inappropriate handling of drilling muds have caused blowouts, leaks, and spills leading to releases of natural gas and environmental contamination. Actions in other states indicate that state regulators will need to consider well standards, mud handling requirements, and other measures to address such events and that on-site inspections to assure compliance, as well as plans to respond to spills and accidents will be needed. Moreover, because of the oil and gas industry's exemption from CERCLA, the state will have to address liability and cleanup from such accidents.

Plikunas, Sarah, Brooks Rainey Pearson, Jonas Monast, Avner Vengosh, and Robert B. Jackson. November 2011. Considering Shale Gas Extraction in North Carolina: Lessons from Other States: Discussion Draft. Duke University Nicholas Institute for Environmental Policy Solutions and Nicholas School of the Environment.

http://nicholasinstitute.duke.edu/climate/policydesign/nc-hydraulic-fracturing

North Carolina Water Resources Congress ponders problems related to navigation, beach nourishment and water supply development

At their annual meeting on November 1, members of the N.C. Water Resources Congress (NCWRC) heard predictions of dire consequences of funding cuts to navigation and beach nourishment projects along the coast; of legal uncertainties about water rights raised by recent court cases; and of a need for more state leadership in planning, permitting, and building reservoirs for municipal water storage projects across the state. The N.C. Water Resources Congress is a "a citizen organization that promotes a partnership among local, state, and federal levels of government to invest in infrastructure and water management improvements that will benefit both economic progress and environmental quality in North Carolina."

Coastal water infrastructure funding in crisis

Beach nourishment and inlet management are critical to tourism, boating and fishing along the North Carolina coast. The state's coastal economy generates $4.9 billion in revenue and 62,100 jobs a year. According to local elected officials and representatives of regional organizations, federal and state cuts in funding for beach protection and inlet dredging threaten the future of this economic engine as well as the safety of boaters along the coast.

The 2011 N.C. Beach and Inlet Management Plan report estimates that federal funding of $9.9 million and state cost-share funding of $3.3 million per year is needed to maintain inlets for navigation. However, according to Colonel Steven Baker, U.S. Army Corps of Engineers (USACE) Wilmington District Engineer, the President's proposed 2012 budget for the USACE "zeros out" inlet dredging and beach nourishment funding, and the current federal ban on earmarks means it is unlikely local governments can look to their Congressional representatives to restore funding for dredging. In addition, the State's 2011-12 budget includes the necessary cost-share funding for federal water resources projects, but little funding for State and local water resources projects and no funding for inlet dredging. The State does have some prior year dredging funds that will be used on a 50/50 cost share with local governments for inlet dredging in FY 2011-2012.

Layton Bedsole, chairman of the Wilmington-New Hanover County, Port, Waterways and Beach Commission, said at the NCWRC meeting that federal and state funding for dredging has been steadily decreasing for a decade, and has reached a level that prohibits full maintenance dredging of N.C. inlets and deepwater ports in Wilmington and Morehead City.

As a result of funding cuts, some inlets have become too shallow for safe navigation and the U.S. Coast Guard has begun the process of removing its channel markers, indicating to boaters that the inlet is not safely navigable. To help address the immediate problem, the N.C. Division of Water Resources (DWR) committed some "prior year" funds to help keep one of the USACE's dredges in operation, and local governments scrambled to find funds to help maintain local inlets. Emergency funding cobbled together by DWR and local governments is allowing dredging to resume at Carolina Beach Inlet, Lockwoods Folly Inlet, Bogue Inlet, and Topsail Inlet. The N.C. Department of Transportation is funding maintenance dredging of its ferry channels and the Oregon Inlet channel.

However, to assure the future navigability of critical inlets, stable long-term funding must be found. Although local governments have not historically funded inlet dredging, local officials seem to have accepted cuts in federal and state funding as inevitable and are strategizing with regional organizations to produce supplemental funding plans that support the region's shallow inlet navigation needs. Coastal communities have for decades committed millions of dollars to cost-share federal and state funds for beach nourishment projects (or in some cases to fund beach nourishment projects completely) by levying sales, occupancy, and prepared meals taxes. Now they face the prospect of taking over a much larger share of funding for beach maintenance along with additional responsibility for inlet maintenance. At the November meeting local officials discussed the revenue potential of various taxes and user fees to fund dredging and beach protection but agreed that any kind of revenue enhancement would be a "hard sell."

In addition to finding millions of additional dollars, local officials must also convince Congress to include contributing authority for non-federal sponsors to allow local governments to fund USACE shore protection projects.

While funding for beach protection and inlet maintenance has reached a crisis point, the issue is not new. In 2009 the N.C. Coastal Resources Commission and its advisory committee passed a resolution asking the N.C. General Assembly to study the possibility of establishing a dedicated fund for coastal

continued on page 9

NCWRC *continued from page 8*

infrastructure using state and local sales taxes and coastal recreational fishing license fees. No such fund has been established.

State needs to help increase water supply

North Carolina's water storage capacity is shrinking, according to Jeff Lineberger, Director of Hydro Strategy and Licensing with Duke Energy. "Most reservoirs in North Carolina are 50 to 100 years old, with withdrawals approaching capacity," said Lineberger speaking at the NCWRC annual meeting. "If we're not building new reservoirs, then supply is declining because of sedimentation. At the same time, we're seeing growing demand."

Lineberger said that the State needs to be out front in building new reservoirs in partnership with local governments. He praised recent legislation (H 609) that will streamline permitting for reservoir development by allowing the N.C. Department of Environment and Natural Resources to be a co-permitee with local governments for federal permits.

Kenny Waldroup, Assistant Public Utilities Director for the City of Raleigh, also praised H 609 saying it gives the state "some skin in the game" of water supply development. Raleigh is currently in the Environmental Impact Statement phase of developing a new reservoir on the Little River in eastern Wake County and faces endangered species and wetland issues that could complicate permitting.

Legal issues with implications for water supply

Charles Case, counsel to the Piedmont Triad Regional Water Authority for the suit brought against PTRWA by hydropower producers on the Deep River, told members of the N.C. Water Resources Congress that local governments and regional authorities seeking to develop water supply reservoirs have a major stake in N.C. Supreme Court action regarding that case.

In *L&S Water Power, Inc. et al. v. Piedmont Triad Regional Water Authority* the Appeals Court upheld a lower court ruling that the PTRWA owes five downstream hydroelectric power producers compensation for their loss of generating capacity because, by constructing the Randleman Dam, it permanently reduced the flow of the Deep River. The ruling is based on a Fifth Amendment interpretation holding that riparian rights held by owners of land bound or traversed by navigable water are vested property rights and that, under the Fifth Amendment, when an entity with eminent domain power exercises that power to take private property, it owes the owner of the property just compensation. PTRWA has asked the N.C. Supreme Court to review the ruling but, as of this writing, the Court has not indicated if it will grant review.

Case said that if the Appeals Court ruling on *L&S Water Power v. PTRWA* stands, it raises questions about the ability of the General Assembly to modify riparian rights through legislation (as it has done in the North Carolina Federal Water Resources Development Law of 1969 which put into place the "impoundment statute") and whether local governments or regional authorities can rely on permits and approvals in certificates issued by the N.C. Environmental Management Commission.

Case also alerted the group to a case currently before the U.S. Supreme Court with implications about ownership of water in rivers. In *PPL Montana, LLC v. State of Montana*, the State of Montana asserts ownership of the beds and banks of three rivers in question and asserts that it holds the rivers in trust for state residents. PPL Montana, LLC, a hydro power company, says the rivers are its private property. Whether the rivers are privately owned or state public trust resources depends whether, under federal law, the rivers were "navigable" when Montana was admitted to the Union. The Montana Supreme Court ruled in favor of the State, and PPL Montana appealed to the U.S. Supreme Court. The case will be argued in December and a decision is expected in June 2012.

Agriculture needs water storage

Pat Harris, Director of the Division of Soil and Water Conservation in the N.C. Department of Agriculture and Consumer Services, discussed a strategic plan for agricultural water resources developed by the N.C. Agricultural Water Work Group with funding from the Altria Group through the N.C. Foundation for Soil and Water Conservation. The plan was called for by the General Assembly in House Bill 1748 passed in 2010. One survey cited in the plan indicates a need for investment of more than $37 million to increase on-farm water storage capacity and a need for $3.5 million annually for technical assistance to help farmers navigate the permitting process for ponds and other structures and for technical assistance. The plan is available at http://www.ncagwater.org/documents/NC_Agricultural_Water_Strategic_Plan.pdf.

Harris also discussed implementation of the Agricultural Water Resources Assistance Program (AgWRAP), which is the first step in fulfilling the strategic plan. The current state budget provides $1 million for AgWRAP, which will select projects and allocate funds for storage construction and implementation of water conservation best management practices. The program will be implemented through local Soil and Water Conservation Districts.

Researchers develop new model for estimating dry ammonia deposition in areas of intensive animal operations

Nutrient over-enrichment is a well documented cause of water quality impairment in North Carolina surface waters. Efforts to fashion effective management programs to control nitrogen inputs have been hampered by lack of good estimates of the amount of nitrogen entering waterbodies from the atmosphere. In this project, investigators set out to improve tools for estimating atmospheric nitrogen inputs in the Neuse and Cape Fear river basins.

Both the Neuse and Cape Fear are home to many large confined animal operations. Globally, domestic animals are the largest source of atmospheric ammonia (NH_3) and in the Neuse and Cape Fear represent a significant fraction of atmospherically derived nitrogen entering terrestrial and aquatic systems

Atmospheric nitrogen reaches waterbodies and land in rainfall as dissolved compounds—"wet" deposition--and as adsorbed compounds on dust particles—"dry" deposition. Gaseous NH_3 is usually dry deposited within a few miles of its source or is converted to ammonium (NH_{4+}). Fine particulate NH_{4+} aerosols stay in the atmosphere longer and are washed out in rain long distances from the source. While good tools exist to estimate the quantity of wet deposition inputs of nitrogen compounds to the ecosystem in eastern North Carolina, the magnitude of dry deposition has not been accurately estimated. With funding from the N.C. Department of Environment and Natural Resources through WRRI, scientists at N.C. State University and the U.S. Environmental Protection Agency in Research Triangle Park tackled the dry deposition question.

To estimate NH_3 dry deposition at field to watershed scales in areas of intensive animal production, the scientists developed a new model that resolves spatial features, such as concentration and deposition gradients around individual animal facilities that are missed by larger regional air quality models. The Semi-Empirical Ammonia Deposition and Emission (SEADE) Model has three parts: a facility-scale NH_3 emission inventory, a spatial model for predicting atmospheric NH_3 concentrations, and a model for predicting net NH_3 air-surface transfer rates. To create the facility inventory, the scientists used the N.C. Division of Water Quality's Confined Animal Feedlot Operations database verified by aerial imagery. They tested three existing models to find the best one for predicting ground-level concentrations of NH_3 and used an existing model that takes into account the competing processes of emission and deposition in foliage-soil (or water) systems to predict net NH_3 air-surface transfer rates.

The SEADE Model estimates that there are 6.9 million kg of dry NH_3 deposition in the Neuse and 13.6 million kg of dry NH_3 deposition in the Cape Fear basin annually. Together the Neuse and Cape Fear dry deposition of 20.6 million kg annually represents 36% of the total emissions of nitrogen compounds calculated from the DENR inventory of animal facilities in the basins and 27% of the emissions calculated using data from the N.C. Department of Agricultural Statistics. This means, the researchers say, that the majority of NH_3 emitted within the two river basins is either wet deposited or transported out of the river basins.

To put the modeled deposition estimates into context, the researchers constructed a nitrogen deposition budget for the Neuse and Cape Fear River basins. This exercise reveals that dry deposition of NH_3 dominates the average watershed-scale deposition budget, exceeding dry deposition of NH_{4+}, its aerosol reaction product, and wet deposition of NH_{4+} by factors of 17 and 2, respectively.

The researchers also modeled a year's positive net dry NH_3 emissions for nine counties. Three of the nine counties, Alamance, Guilford, and Carteret, have greater than 20% of their area within the Neuse or Cape Fear river basin. Of those three counties, Alamance exhibited the greatest total emission, 160,000 kg NH_3 for the year, an average of 1.48 kg NH_3 per hectare. In contrast, five counties account for greater than half the total dry NH_3 in the study area with Sampson County receiving over 3.3 million kg of dry deposited NH_3 throughout the year. Although ranked sixth in total deposition, Green County has the greatest per hectare average at 14.3 kg NH_3 per hectare.

The scientists point out that the SEADE Model needs some improvement in its ability to calculate dry deposition for different land cover classes and that better data on animal facilities and more measurement sites of air concentrations near facilities would improve its accuracy. Nevertheless, they say, the model offers great promise in linking the complex, field-scale mechanistic processes with the large, regional-scale deposition models.

Walker, John T., Robert E. Austin, and Wayne P. Robarge. (2010) Development of the Semi-Empirical Ammonia Deposition and Emission (SEADE) Model for Application to North Carolina Watersheds. Report No. 394 of the Water Resources Research Institute of the University of North Carolina.

River-based Bayesian Maximum Entropy framework yields better estimation of mercury in fish tissue

Methylmercury, a neurotoxin, has been found in fish tissue at sampling stations across North Carolina, and a fish consumption advisory for mercury is in effect for Largemouth Bass in all surface waters of the state. The N.C. Division of Water Quality is developing a statewide total maximum daily load (TMDL) for mercury.

The highest concentrations of methylmercury in fish tissue have been measured at sampling points in Eastern North Carolina. However, due to time and resource constraints, it is difficult to directly measure fish tissue mercury on a basinwide scale. Furthermore, bioaccumulated mercury may change gradually over time at individual locations, depending upon the characteristics of the water body and fish community. It is, therefore, important to have a robust method for estimating fish tissue mercury across broad spatial scales to accurately identify areas that have the potential for high levels of bioaccumulated mercury.

In this project, researchers at UNC-Chapel Hill built upon earlier work in which they incorporated river distances into the geostatistical estimation of water quality parameters using the Bayesian Maximum Entropy (BME) framework (river-BME). For the purpose of estimating space/time fish tissue mercury, they used river distances along with secondary variables pH and water column mercury within the BME framework. The areas under investigation were the Cape Fear and Lumber River Basins in Eastern North Carolina.

With the help of collaborators at N.C. State University, pH data were extracted from a database compiled from the N.C. Division of Water Quality Fish Tissue Assessment Program and combined with additional pH data from the National Water Information System through the United States Geological Survey for the Cape Fear and Lumber basins between 1990-2004. Surface water total mercury data collected by NCDWQ as part of the Eastern Regional Mercury Study were combined with data downloaded from the NWIS.

Using their river-BME framework with pH and water column mercury as secondary variables, the researchers produced estimation maps that were on average 16% more accurate than the classical approach that ignores river distances and may not include secondary variables. Both secondary variables contributed to an overall decrease in estimation error, albeit small due to limited data and a high degree of uncertainty in the relationships between these secondary variables and fish tissue mercury. The use of river distances (river-BME) contributed 13% of the reduction in estimation error.

The researchers say that in the combined Lumber-Cape Fear basin, the median estimate of fish tissue mercury exceeded the EPA action level of 0.3 parts per million (ppm) in more than 90% of river miles for a majority of the study period. More than 50% of river miles had median estimates of fish tissue mercury that exceeded the North Carolina level of 0.4 ppm for almost the entire study period. In addition, during the years 1990-1994, between 1-4% of river miles had a median estimate above even the most lenient action level of 1.0 ppm set by the FDA. No river miles had a median estimate of fish tissue mercury exceeding the FDA action level since 1999, according to their results.

The scientists conclude that their study shows that river-BME provides a good framework for decreasing the estimation error as more data on secondary variables become available. They also suggest that incorporating additional information about species type and habitat patterns as well as dissolved organic carbon, sediment data and other variables could result in even more accurate maps. Such maps can aid environmental managers in identifying important bioaccumulation factors and areas where sampling and advisory resources should be targeted.

An animated GIF depicting the space/time distribution of fish tissue mercury in the Cape Fear and Lumber Basins, every 180 days, between 1991-2004, can be viewed at: http://www.unc.edu/depts/case/BMElab/studies/HgFish_NC/CapefearLumber_HgFish_1991_2004.GIF.

Money, Eric S. and Marc L. Serre. 2010. Space/Time Estimation of Fish Tissue Mercury Along Unsampled Streams in Eastern North Carolina. Report No. 393 of the Water Resources Research Institute of The University of North Carolina.

Upcoming Events

Save The Date!

Water Resources Research Institute 2012 Annual Conference and NCWRA Symposium

March 27-28, 2012

Jane S. McKimmon Center
Check the WRRI website for information:
http://go.ncsu.edu/wrriac

North Carolina Water Resources Association Luncheon and Forum

"A Fundamental Change in Managing our Community Water Infrastructure"

February 6, 2012

Jane S. McKimmon Center
Put the date on your calendar and check
http://www.ncwra.org for more information.

CHECK OUT THE NEW WRRI WEBSITE

The Water Resources Research Institute of The University of North Carolina System proudly announces the official launch of its new and improved website. Events, past and present, research and funding opportunities, current publications, and partnerships are now clearly displayed on their own pages. Partnering with the D. H. Hill library at NC State University, we've uploaded our extensive collection of research reports, annual programs, and newsletters into a user-friendly technical repository. This makes the history of Institute-supported research readily available and searchable, and will allow us to effectively and efficiently share future research.

To optimize your experience with the new site, we recommend you upgrade your web browser to Internet Explorer 8, and the most current version of Mozilla Firefox, Safari , or Google Chrome. You may send feedback to water_resources@ncsu.edu.

Click here http://www.ncsu.edu/wrri/ to begin exploring our new site!

REGISTER NOW

AWWA Water Audit Software Training

January 19, 2012
Jane S. McKimmon Center,
Raleigh, NC
12:30-4:00pm

March 6, 2012
UNC-CH School of Government,
Chapel Hill, NC
1:00-4:30pm

Cost: $30
Register or download form at:
http://go.ncsu.edu/wateraudit

With funding from the National Science Foundation the Nicholas School of the Environment and the Duke Environmental Law & Policy Forum at the Duke Law School is sponsoring

Environmental and Social Implications of Hydraulic Fracturing and Gas Drilling in the United States: An Integrative Workshop for the Evaluation of the State of Science and Policy

The first day of the workshop is open to the public:
Jan 09, 2012
from 08:00 AM to 03:00 PM
Love Auditorium, Levine Science and Research Center, 308 Research Drive, Durham
Registration is required and space is limited:
http://www.nicholas.duke.edu/hydrofrackingworkshop2012/workshop